	CDMA 9600, Omni	CDMA 4800, Omni	CDMA 9600, Omni	CDMA 4800, Omni
HPA Power	-2.0 dBW	-2.0 dBW	-2.0 dBW	-2.0 dBW
E/S Antenna Gain	4.0 dB	4.0 dB	4.0 dB	4.0 dB
Path Loss	-187.5 dB	-187.5 dB	-187.5 dB	-187.5 dB
Spacecraft Antenna Gain	37.2 dB	37.2 dB	37.2 dB	37.2 dB
Data Rate	9,600 bits/sec	4,800 bits/sec	9,600 bits/sec	4,800 bits/sec
-10•log(Data Rate)	-39.8 dB/Hz	-36.8 dB/Hz	-39.8 dB/Hz	-36.8 dB/Hz
Eb	-188.1 dBW/Hz	-185.1 dBW/Hz	-188.1 dBW/Hz	-185.1 dBW/Hz
Spreading Bandwidth	8.064E+06Hz	8.064E+06Hz	8.064E+06Hz	8.064E+06Hz
10•log(Data Rate/Spr. BW)	-29.2 dB	-32.3 dB	-29.2 dB	-32.3 dB
% of Users in Beam	15%	15%	15%	15%
Voice Duty Cycle	40%	40%	40%	40%
Preamble Power	0.3 dB	0.6 dB	0.3 dB	0.6 dB
Total Capacity	3,940 Erlangs	8,216 Erlangs	4,256 Erlangs	8,508 Erlangs
Cap.•Duty Cycle•% of Users	236 Erlangs	493 Erlangs	255 Erlangs	510 Erlangs
10•log(above)	23.7 dB	26.9 dB	24.1 dB	27.1 dB
Pseudo-Noise Density, Io	-193.3 dBW/Hz	-189.9 dBW/Hz	-193.0 dBW/Hz	-189.7 dBW/Hz
Total Sat. Noise Temperature	398.0 °K	398.0 °K	398.0 °K	398.0 °K
Thermal Noise Density, No	-202.6 dBW/Hz	-202.6 dBW/Hz	-202.6 dBW/Hz	-202.6 dBW/Hz
Thermal, Eb/No	14.5 dB	17.5 dB	14.5 dB	17.5 dB
Pseudo Noise, Eb/Io	5.2 dB	4.8 dB	4.9 dB	4.6 dB
Combined, Eb/(No+Io)	4.7 dB	4.5 dB	4.4 dB	4.4 dB
Fading Margin	-1.4 dB	-1.4 dB	-1.4 dB	-1.4 dB
Modem Implementation Loss	-0.5 dB	-0.5 dB	-0.5 dB	-0.5 dB
Eb/(No+Io) Minimum	2.5 dB	2.5 dB	2.5 dB	2.5 dB
Excess Link Margin	4.0 dB	4.0 dB	2.0 dB	2.0 dB

Table 2.2: L-Band Return Link Budget Calculations

3. Calibration Procedure

Because of the problems of accurately separating the signal from the noise and measuring each in the field environment and the potential nonlinearities in the RF equipment, the modem was used to measure its own receive signal-to-noise ratio.

This calibration procedure is based on the fact that the modem uses a *Signal + Noise* AGC over the full spreading bandwidth—much wider than the coded symbol rate and is therefore very nearly a noise only AGC. Also, an unmodulated *Pilot* signal is always transmitted (but not always used). This pilot is created and combined with the unit data digitally and a single DAC is used to transmit both. Therefore, once the pilot signal-to-noise is calibrated, one knows the unit data signal-to-noise with great accuracy.

Special calibration software that reports the pilot signal amplitude after coherent combining for nearly a second and a spreadsheet that converts this number to a unit data signal to noise ratio (Table 3.1) were used. These were checked for accuracy against the In-Plant Calibration procedures and the two agreed to within 0.2 dB when the In-Plant procedures were valid (receiver front-end noise is negligible).

Eb/No	Acc. Pilot Value							
2.5	0	0	3	0	C	A	3	B
2.9	0	0	3	3	1	6	E	1
3.5	0	0	3	6	B	E	4	5
3.9	0	0	3	9	5	2	B	E
4.5	0	0	3	D	6	C	4	5
4.9	0	0	4	0	5	1	5	5
5.5	0	0	4	4	E	A	E	C
5.9	0	0	4	8	2	A	6	8
6.5	0	0	4	D	5	3	A	F
6.9	0	0	5	0	F	8	A	0
12.5	0	0	9	A	4	9	9	5
13.5	0	0	A	D	1	D	0	4
14.5	0	0	C	2	3	C	8	3
15.5	0	0	D	9	E	F	D	2
16.5	0	0	F	4	8	7	7	4

***Table 3.1:** Accumulated Pilot Values For Useful Eb/No's*

3.1 Field Procedures

This procedure used the following sequence:

1. Calibrate Downlink Thermal signal-to-noise at the Mobile Unit.
2. Calibrate Downlink Other User signal-to-noise at the Mobile.
3. Calibrate Uplink Thermal and Other User signal-to-noise at the Hub.

The LNA noise combined with a Gaussian Noise generator were used to generate the Downlink Thermal Noise, a broad-band Gaussian Noise generator plus the power amplifier intermodulation products were used to create the Downlink Other User Noise, and the LNA noise combined with a Gaussian Noise generator were used to create the Uplink Thermal and Other User noise.

3.1.1. Downlink Thermal Signal-to-Noise Calibration

1. Start the Calibration software in both the Hub and Mobile modems.
2. Turn off the Downlink Other User Noise.
3. Use a temporary E_b/N_0 that is the nominal E_b/I_0.
4. Use the Pilot Calibration Spreadsheet (Table 3.1) to calculate the Accumulated Pilot value that corresponds to the temporary E_b/N_0 in step 3.
5. Adjust the transmit attenuator at the Hub until the correct Accumulated Pilot value, calculated in 4, is produced in the Mobile modem.
6. Reduce the value of the transmit attenuator at the Hub by the I_0/N_0 ratio. This increases the Downlink E_b/N_0 to its operating value.

7. The Downlink Thermal Signal-to-Noise ratio is now calibrated.

3.1.2. Downlink Other User Signal-to-Noise Calibration

8. Turn on the Downlink Other User Gaussian Noise generator—C/N_0 test set.
9. Use the Pilot Calibration Spreadsheet (Table 3.1) to calculate the Accumulated Pilot value that corresponds to the combined Downlink Thermal E_b/N_0 plus Other User E_b/I_0. This combination will be referred to as the Downlink $E_b/(I_0+N_0)$.
10. Adjust the C/N_0 on the Gaussian Noise generator until the correct Accumulated Pilot value, calculated in 9, is produced at the Mobile modem.
11. The Downlink Other User Signal-to-Noise ratio is now calibrated. The value of C/N_0 on the Other User Gaussian Noise test set may differ from the value used in the In Plant Tests because the non-linearity of the TWT may cause intermodulation products that decrease the signal-to-noise ratio.

3.1.3. Uplink Thermal and Other User Signal-to-Noise Calibration

12. Load the normal Mobile software in the Mobile modem.
13. Adjust the transmit power headroom of the Mobile unit to the desired level. This is the amount that the Mobile power may be increased from nominal before the maximum power level is reached.
14. Move the Mobile Vehicle until a nominal position is reached.
15. Use the Pilot Calibration Spreadsheet (Table 3.1) to calculate the Accumulated Pilot value that corresponds to the Uplink combined Thermal E_b/N_0 plus Other User E_b/I_0—Uplink $E_b/(I_0+N_0)$.
16. Adjust the Mobile transmit attenuator until the correct Accumulated Pilot value, calculated in 15, is produced at the Hub modem.

4. Summary of Tests

The weaker link in a CDMA system is the Uplink. Also, the voice quality that is produced is the ultimate test and not the bit error rate or other measurements. The factors that degrade the quality of the signal are the obstructions and reflecting objects that cause multipath and fading.

For all of the reasons above, the primary record of the tests is the video tape that recorded on the video, the Mobile vehicle as it drove through the test range and on the audio, the voice from the Mobile to the Hub after it was encoded, transmitted through the modem and then decoded back to audio.

A test run was done for each of the Fading Environments available (Moderate Fading and Heavy Fading with Shadowing) at several Signal-to-Noise ratios (+2 dB and +4 dB margins) and with different data rate Vocoders (Entropic 4800 bps and M/A-COM 9600 bps Vocoders). Before each set of tests, a calibration was performed. All the test runs listed below were recorded on video tape for later evaluation.

4.1. Testing 4800 bps Vocoder With +2 dB Margin in Heavy Fading and Shadowing Environment

Using the Entropic 4800 bps Vocoder The system was calibrated for a C/No of 41.5 db, resulting in a +2 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first west and then east on Grand Avenue.

4.2. Testing 4800 bps Vocoder With +4 dB Margin in Heavy Fading and Shadowing Environment

Using the Entropic 4800 bps Vocoder The system was calibrated for a C/No of 43.5 db, resulting in a +4 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first west and then east on Grand Avenue.

4.3. Testing 9600 bps Vocoder With +2 dB Margin in Heavy Fading and Shadowing Environment

Using the M/A-COM 9600 bps Vocoder The system was calibrated for a C/No of 44.5 db, resulting in a +2 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first west and then east on Grand Avenue.

4.4. Testing 9600 bps Vocoder With +4 dB Margin in Heavy Fading and Shadowing Environment

Using the M/A-COM 9600 bps Vocoder The system was calibrated for a C/No of 46.5 db, resulting in a +4 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first west and then east on Grand Avenue.

4.5. Testing 4800 bps Vocoder With +2 dB Margin in Moderate Fading Environment

Using the Entropic 4800 bps Vocoder The system was calibrated for a C/No of 41.5 db, resulting in a +2 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first north and then south on Riverside Drive.

4.6. Testing 4800 bps Vocoder With +4 dB Margin in Moderate Fading Environment

Using the Entropic 4800 bps Vocoder The system was calibrated for a C/No of 43.5 db, resulting in a +4 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first north and then south on Riverside Drive.

4.7. Testing 9600 bps Vocoder With +2 dB Margin in Moderate Fading Environment

Using the M/A-COM 9600 bps Vocoder The system was calibrated for a C/No of 44.5 db, resulting in a +2 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first north and then south on Riverside Drive.

4.8. Testing 9600 bps Vocoder With +4 dB Margin in Moderate Fading Environment

Using the M/A-COM 9600 bps Vocoder The system was calibrated for a C/No of 46.5 db, resulting in a +4 dB margin in both Uplink and Downlink directions at the east end of the Grand Avenue. The test was then conducted with the car travelling first north and then south on Riverside Drive.

EXHIBIT I.

Draft Final Report for Hughes Communications on System Studies for a CDMA Mobile Satellite System

October 28, 1986

QUALCOMM, INC.

This report presents the results of work done under contract HCSS-000267-05, tasks one and two. The first section, **Signal Structures**, briefly reviews the CDMA System described in the previous report as well as describing the modifications that we have incorporated in the signal design as a result of this contract. The next section, **Fading Modeling and Mitigation**, describes the fading modeling during the early phases of the contract and the methods proposed to mitigate the effects of that fading. The section, **Acquisition and Tracking Algorithms**, describes the sequences proposed for receive and transmit acquisition by the Mobile unit. **Demonstration System High Level Design** presents the high level hardware design for a demonstration unit suitable for field testing. This section includes hardware size estimates. The sections, **Hub to Mobile Implementation and Simulation** and **Mobile to Hub Implementation and Simulation**, present the design of and the methods used to implement a software simulation of both the uplink and downlink paths in the presence of fading. Performance results of these simulations are then given. The Last Section, **System Link Budgets**, uses the details and results of the other sections to update the Link Budgets that estimate the capacity of the system.

The appendices contain supporting information. **Signal-to-Noise Ratio in CDMA Systems** explains in detail the self-noise or interference that a CDMA system encounters and how that affects system capacity. This information is then used to calculate the capacity assuming several chip filtering alternatives. **Production Unit Cost Estimates** gives some rough estimates of what a production CDMA terminal would cost. **Simulation Code Listings** provides the listings of the simulations used to produce the data in this document.

Signal Structures

This section presents the details of the waveforms and signals used in the proposed CDMA MSS system. First, the detailed characteristics of the Chip Waveform and its spectrum are presented. Next, an overview of the Downlink signals is presented. Here the relationships between the Pilot Sequence, the Broadcast Channel and normal data are described. The last part of this section presents an overview of the Uplink Signals. In particular, the new concept of a fallback to Differential PSK (DPSK) is described.

Chip Waveform and Spectrum

Figure 1-1 shows the block diagram of the modulation used for all the signals in the CDMA MSS system. The Tx Filters shown are digital Finite Impulse Response (FIR) filters that are close approximations to ideal matched filters of the analog IF receive filter used in the demodulator. For the demonstration system, the spectral template shown in figure 1-2 has been assumed.

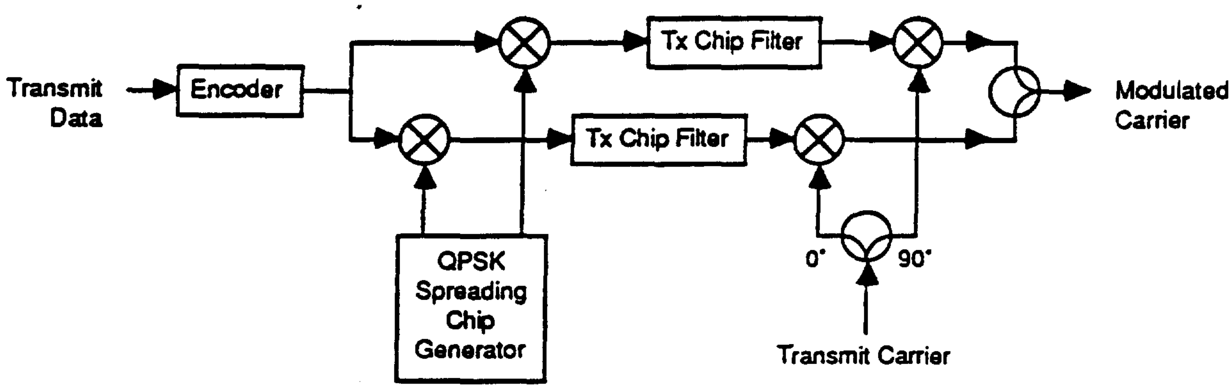


Figure 1-1 — Modulation Block Diagram

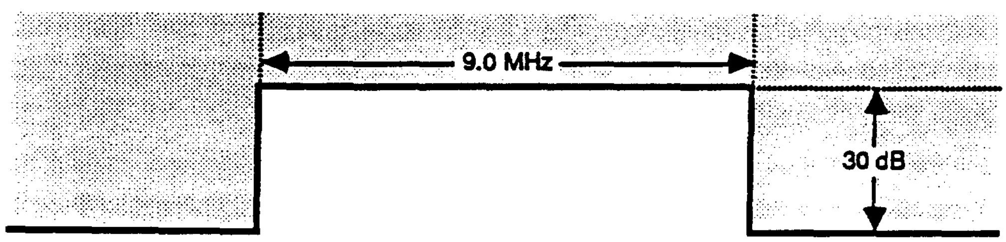


Figure 1-2 — Modulation Spectral Template

The fifth-order elliptic elliptic filter chosen meets the spectral template with a chip rate of 8.064 MHz. The digital filter produces nearly the same response as an analog filter driven by an impulse train at the chip rate. The impulse train response can easily be realized with the digital FIR filter. The exact parameters ot the elliptic filter are 0.18 dB passband ripple, 30.3 stopband attenuation and a 3 dB bandwidth of 8.064 MHz. Figure 1-3 shows the power spectrum of this filter against the spectral template. Other chip filters were considered. These are listed in appendix I with a fuller discussion of the factors that led to the choice of the elliptic filter.

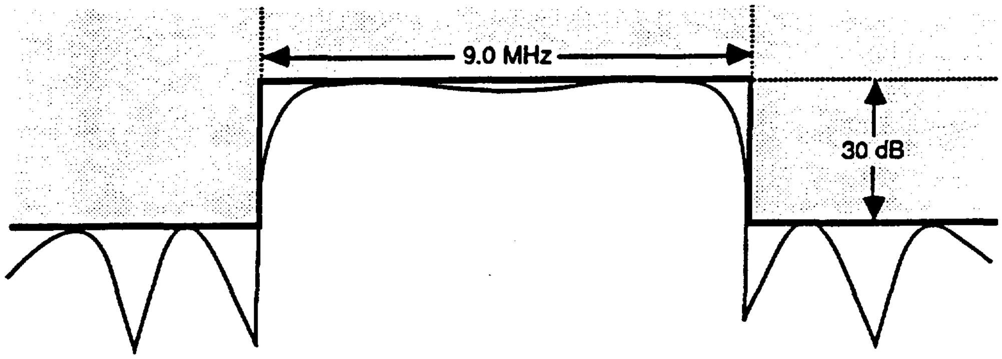


Figure 1-3 — Spectrum of Fifth-Order Elliptic Filter

Downlink Signals

The downlink signal structure centers around a single CDMA pilot sequence shared by all users. This pilot sequence is used for several functions. It consists of the spreading sequence originating from a short (length 4095) PN generator. The pilot sequence is unmodulated, i.e. the "Tx Data" in figure 1-1 is the all zero sequence. These features provide several benefits:

- The single pilot shared by all of the users of the system means that the CDMA pilot can be given a much better signal to noise ratio (S/N) and not degrade the S/N of the users to any great degree. This better S/N simplifies the design of the Mobile Unit as well as enhancing its acquisition and tracking performance.
- The unmodulated sequence simplifies both chip time and carrier phase tracking. This important at the low Es/Io where the system is operated and is especially important in fading conditions.
- The short length of the sequence allows quick acquisition of code timing when the Mobile Unit is begins its acquisition procedure.

Another—synchronous with the pilot—length 4095 sequence is used to modulate the broadcast data channel. This channel carries information for initializing the long (unit) sequence PN generator that is specific to each unit, information for initializing the phase of the information bit and code symbol counters relative to the unit sequence generator. This channel is designed so that it may be received as soon as the Mobile Unit has acquired the pilot sequence. The data rate is 1969.23 bits/sec or one information bit every 4095 chips—and one code symbol every 1365 chips. This means that synchronization for decoding data with the Viterbi Decoder is guaranteed as soon as the pilot sequence has been acquired. The data in the broadcast channel follows a fixed frame structure shown in figure 1-4. Each frame starts with a Frame Sync Word, followed by the system code state and data phase for the end of the third frame following this frame, other system data and a CRC for error detection.

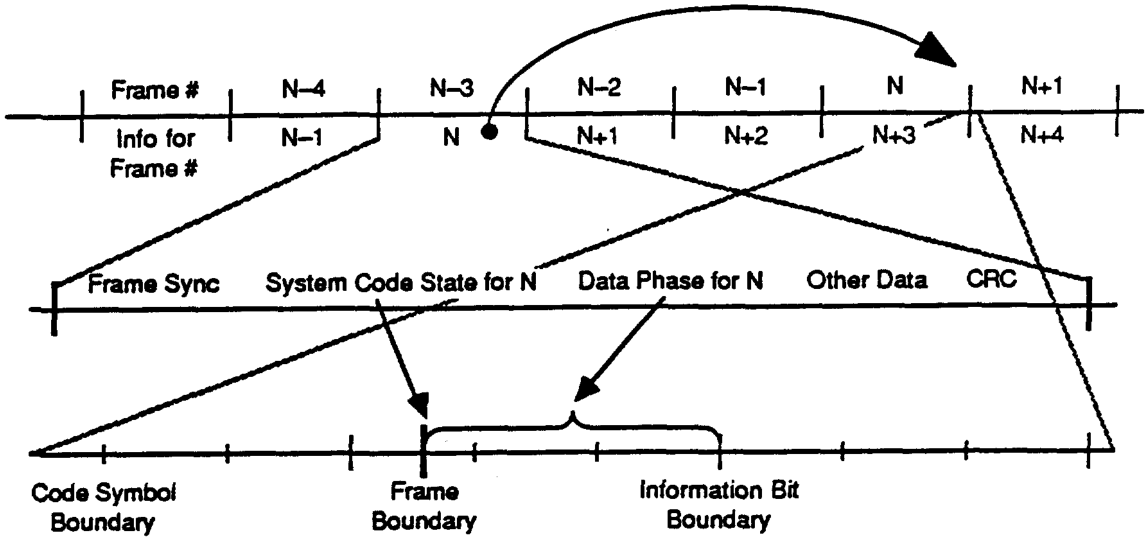


Figure 1-4 — Downlink Frame Information and Structure

The unit addressed data is spread by a length 2^{41}-1 PN generator. All units use the same generator with unit specificity provided by time offsets in the sequence. 2^{41}/8.064 MHz/0.25 sec. = 1,090,785.35. Thus a single generator can provide over one million codes with offsets far in excess of any possible differential delays between unit caused by location. Even if one million addresses proves to be inadequate, this capacity can be easily increased by using additional—and longer—sequences.

Each unit must transform the system code state into a unit code state. Because the unit codes are time delayed versions of the system code, all that needs to be done is to time shift the system code state. The following equation shows how the time shift may be accomplished with a vector-matrix multiply: $X(t+\tau) = X(t) \times D(\tau)$, where $X(t)$ is the system code state at time t, $X(t+\tau)$ is the code state of a unit that has a delay of τ and $D(\tau)$ is the delay matrix. The size of the vectors, $X(t+\tau)$ and $X(t)$ is 41 bits and the size of the matrix, $D(\tau)$, is 41 bits by 41 bits. The matrix is computed offline and stored in each unit at manufacture time. The three frame delay allows time for the vector-matrix multiply in the Mobile Unit microprocessor.

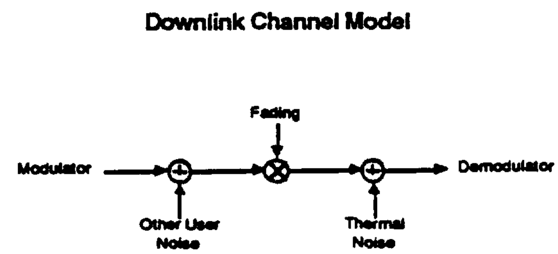
Uplink Signals

The uplink signal structure is very similar to the downlink signal structure. The major differences lie in when the signals are used. In addition, the uplink has a fallback mode to Differential PSK (DPSK).

No pilot is transmitted by the Mobile Unit. The Mobile Unit starts the transmit synchronization process by transmitting a delayed version of the broadcast channel spread by one of a small set of length 4095 sequences. This broadcast channel contains the Mobile Units understanding of system code state and is used by the Hub to initialize its unit-specific sequence generator—this is, in effect, how the round trip time delay is measured and accommodated. Once the startup procedure is complete, the mobile stops the broadcast channel transmission and only transmits its unit data covered by its unit sequence generator.

Fading Modeling and Mitigation

Figure 2-1 shows the channel model for the Uplink and Downlink paths. It is important to notice how "Other User" Noise, Thermal Noise and Fading affect the two paths differently. Because the largest noise source is "Other User" Noise, the effects of fading on capacity are much more severe on the uplink path than on the downlink. This happens because the fading attenuates the desired signal and the "Other User" Noise on the downlink, leaving the E_S/I_0 relatively unchanged, but on the uplink the signal is attenuated and the "Other User" Noise is not, degrading E_S/I_0 directly.



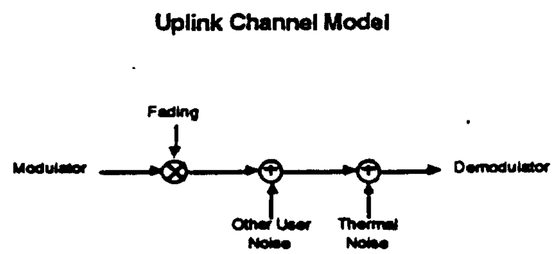


Figure 2-1 — Channel Models

For these reasons, the effort on modeling on the fading has been concentrated on the Uplink path. Two software models were used in simulating the fading. These were the "Many Point Scatterer" model and the "Butterworth" model. Interleaving and Spatial Diversity were then investigated as mitigation techniques against these models to evaluate their effectiveness. These results were used to estimate the Es/Io margin that would be needed for several classes of users. This data together with a hypothetical mix of users was then used to calculate the capacity of the Uplink system.

Many Point Scatterer Model

The Many Point Scatterer model consists of a plane wave impinging on 50-500 point scatterers placed on a two dimensional plane. Each scatterer is assumed to scatter with an omni-directional pattern and a random reflection coefficient between 0.0 and 1.0. Figure 2-2 shows an example of the locations of the scatterers for a 50 point run. A receiver is then moved through the scatterers. The strength of the signal from each scatterer is calculated based on reflection coefficient, the autocorrelation of the spread spectrum chip filter and the $1/r^2$ loss from the scatterer and the receiver. The phase of the signal is calculated based on the path length to the scatterer. The average signal strength from all of the scatterers is adjusted to set the "K" factor for Rician scattering. An undisturbed signal is then added, vectorially, to the signals from all of the scatterers. Signal strength and phase samples were then collected every 0.02 meters—because the wavelength is 0.2 meters, this is 10 samples per wavelength.

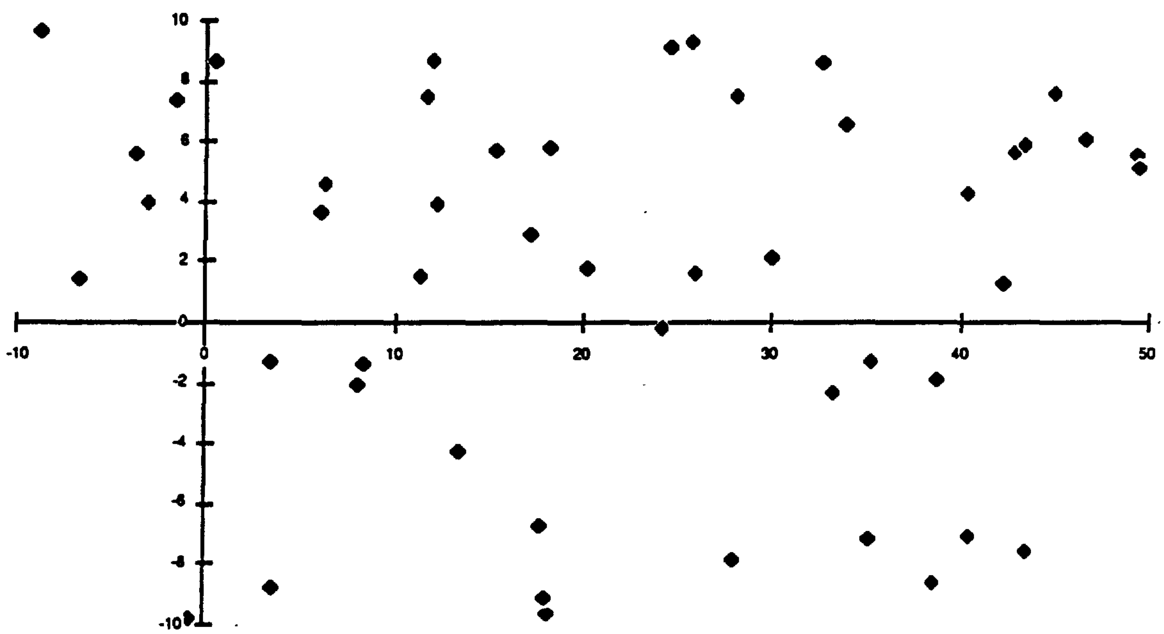


Figure 2-2 — Locations of 50 Random Scatterers

Butterworth Model

This model is based on the work of Butterworth[1] who made many field measurements, constructed a plausible laboratory model and then showed that his field data matched this model well. Figure 2-3 shows the major components of the Butterworth model. All of Butterworth's work was done on CW or single frequency signals—no spread spectrum gain was assumed.

[1] J.S. Butterworth, *Propagation Measurements for Land-Mobile Satellite Systems at 1542 MHz*, Communications Research Centre Technical Note No. 23, Department of Communications, Ottawa, Canada, August 1984.

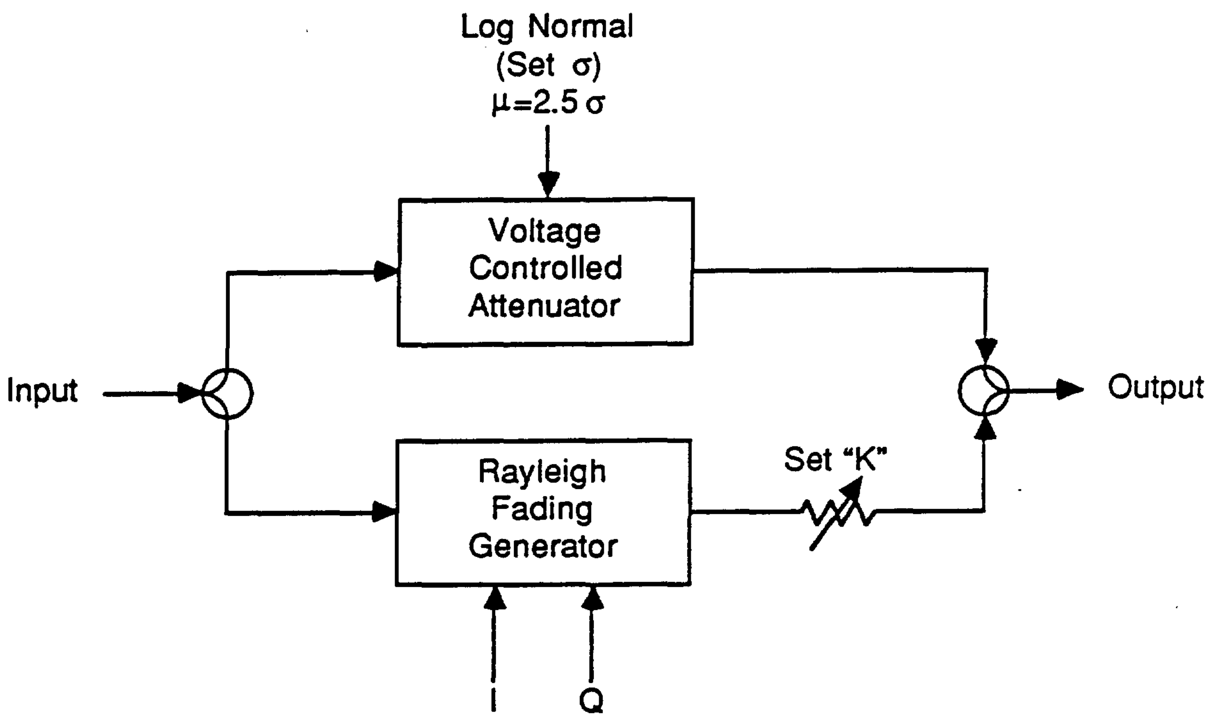


Figure 2-3 — Butterworth Model

Fading Mitigation Schemes

Three fading and shadowing mitigation schemes were considered:

- Uplink Power Control
- Interleaving
- Spatial Diversity

While uplink power control was not simulated, it was considered. The conclusion was that very fast (<25ms) power control was not practical since frequency selective fading is decorrelated on transmit and receive frequencies and fast power control would only increase the signal strength variations. However, moderate (50-200ms) and slow (>.5 sec.) uplink power control can be useful. Interleaving is a scheme by which symbols are transmitted over the channel in non-sequential order. Figure 2-4 shows an example of a 12 symbol interleaver. Since fading will affect adjacent symbols, interleaving tends to spread out the fading affects. When combined with coding, corrupted symbols can be corrected. The major disadvantage with interleaving is the delay introduced in the interleaving/deinterleaving operations. A 25 msec interleaver generates a 50 msec delay. The third scheme, spatial diversity, consists of two antennas separated by some distance (one meter, for example). A one meter separation is five wavelengths at 1.5 GHz and is sufficient to decorrelate the Rician fading.

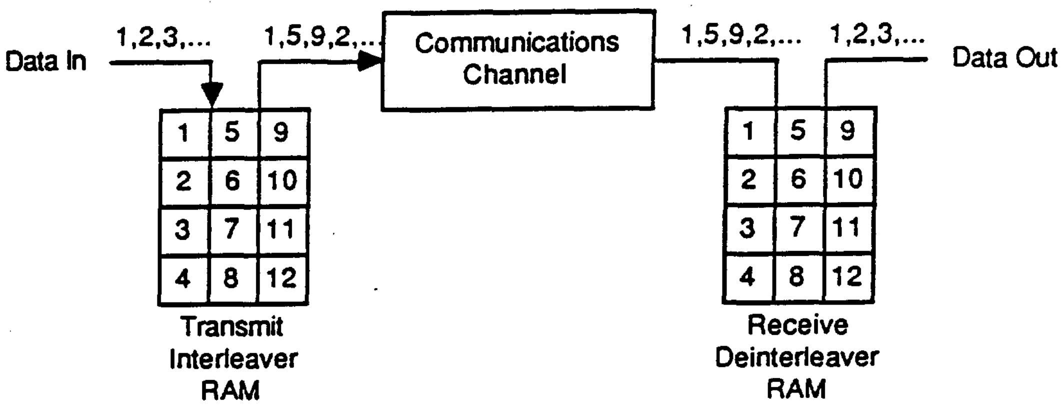


Figure 2-4 — Example Interleaver

Fading Simulation Results

Figures 2-5 through 2-8 show the results of the of the Butterworth fading model simulation under different environments using the fading mitigation schemes described above (uplink power control was not simulated). The plots are cumulative probability curves showing the probability of fade depth. Two interleaver lengths are shown on each plot. The .26m interleaver is approximately a 25 msec interleaver at 25 mph. The .5m interleaver is about a 50 msec interleaver at 25 mph. The 1m diversity curves represent the spatial diversity scheme with a 1m separation between the antennas. In addition, curves are shown combining the interleaver and spatial diversity schemes. The *normal* curve is the result if no action is taken to ease the affect of fading. It is interesting to note that .26m interleaving and 1m diversity applied separately yielded about the same benefit. Better performance is obtained when they are combined. The greatest gain is obtained when .50m interleaving and 1m diversity are combined. However, it is felt that the delay introduced by a .50m interleaver would be excessive.

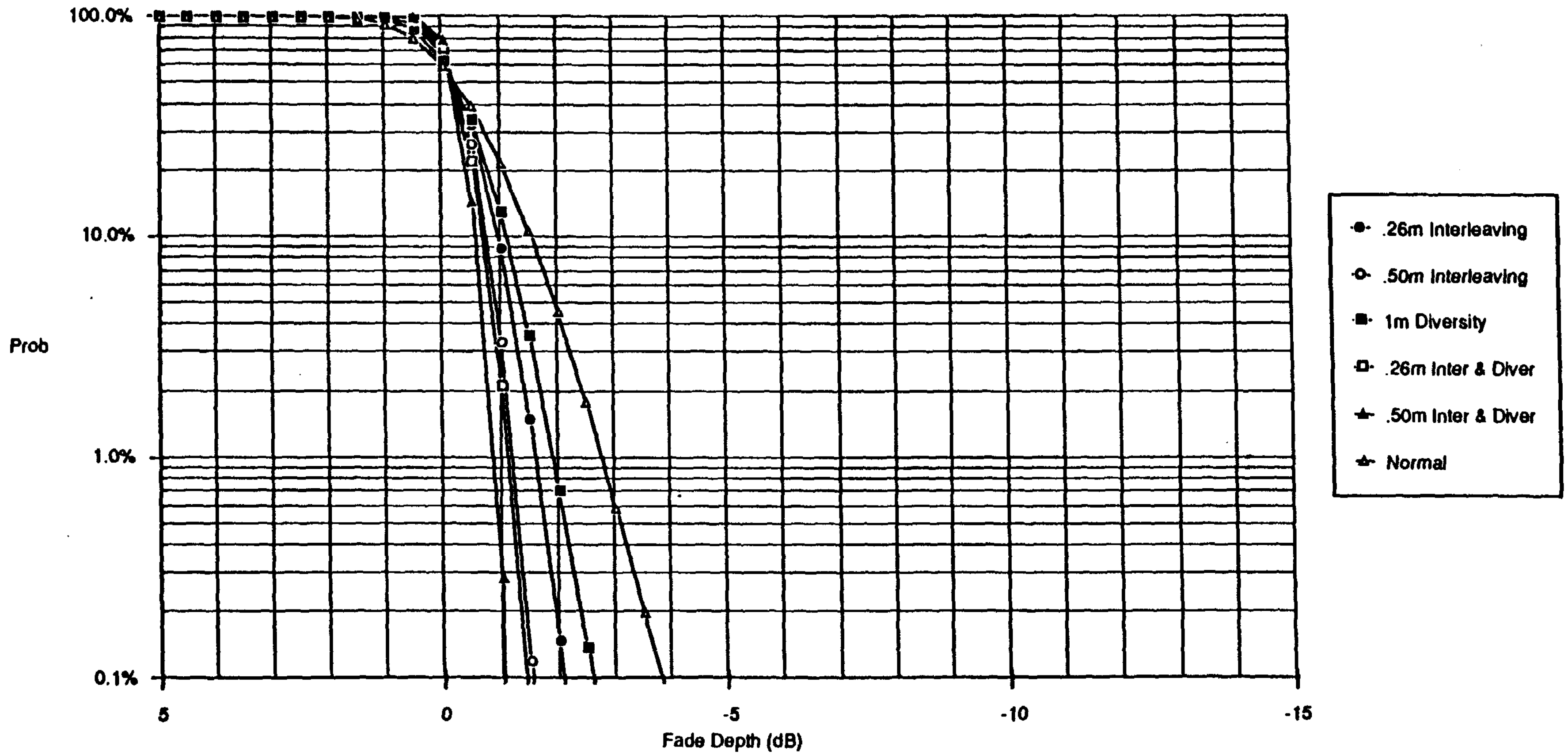


Figure 2-5
Butterworth Model (K=40, No Shadowing)

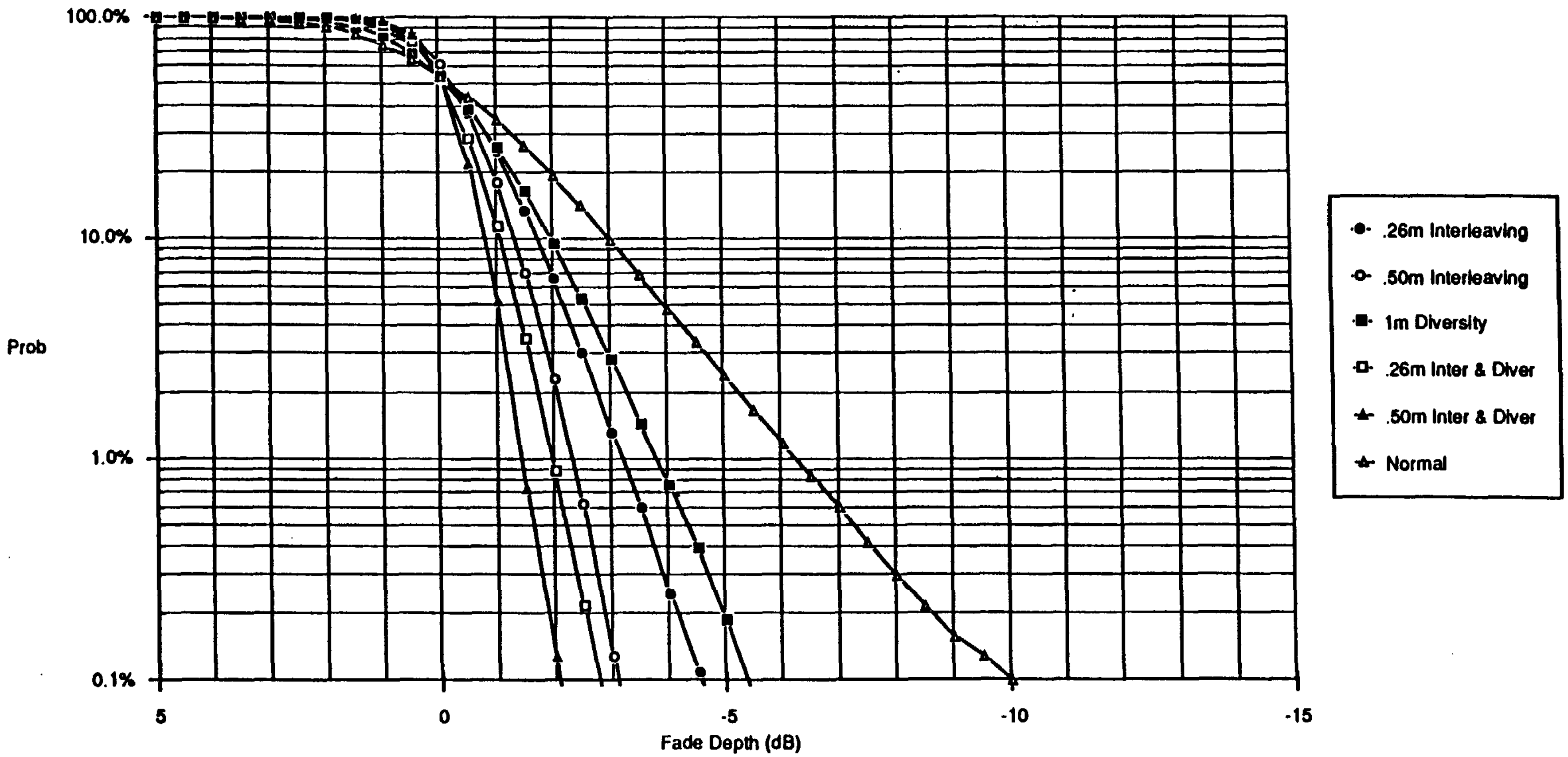


Figure 2-6
Butterworth Model (K=10, No Shadowing)

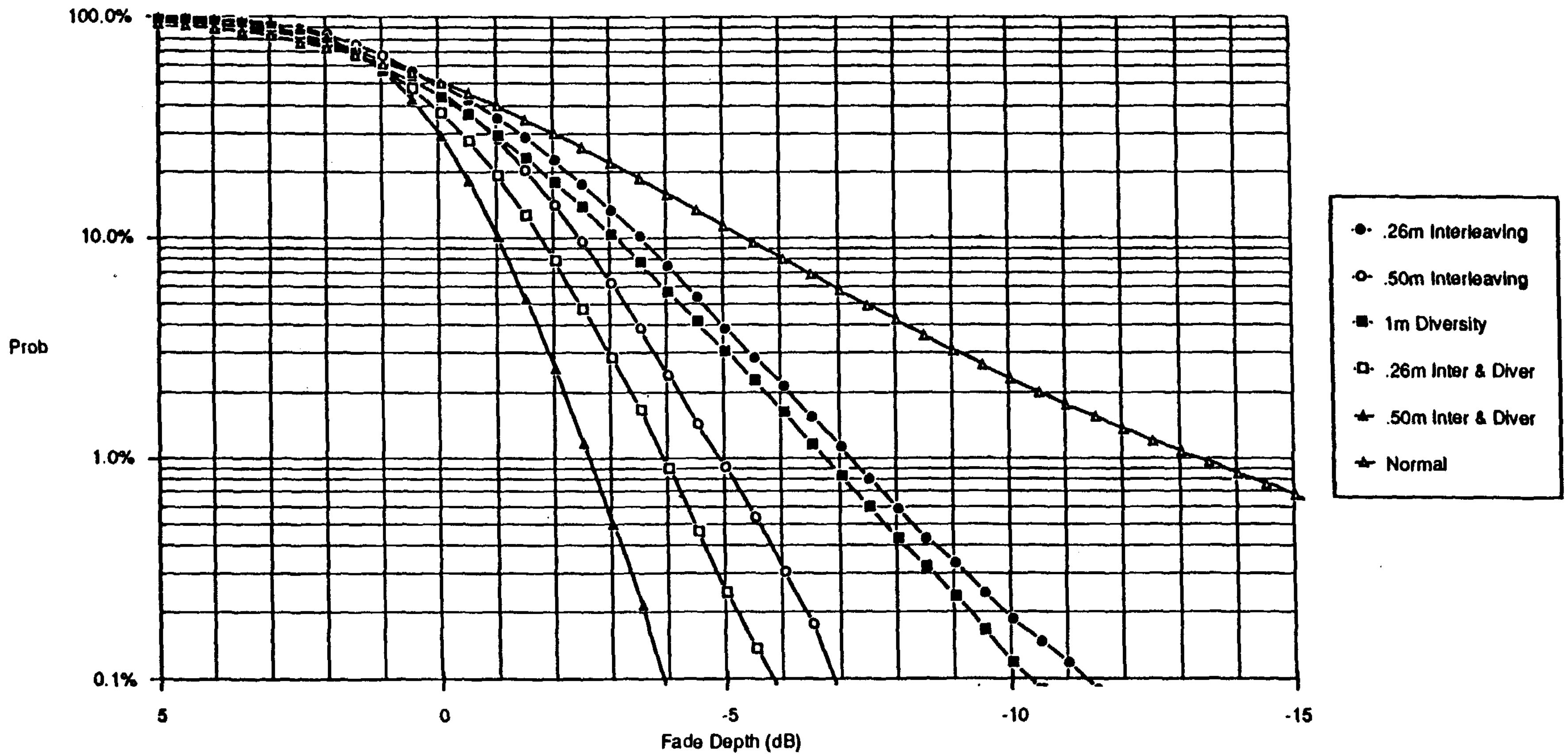


Figure 2-7 Butterworth Model
(K=10,μ=0,Sigma=3)

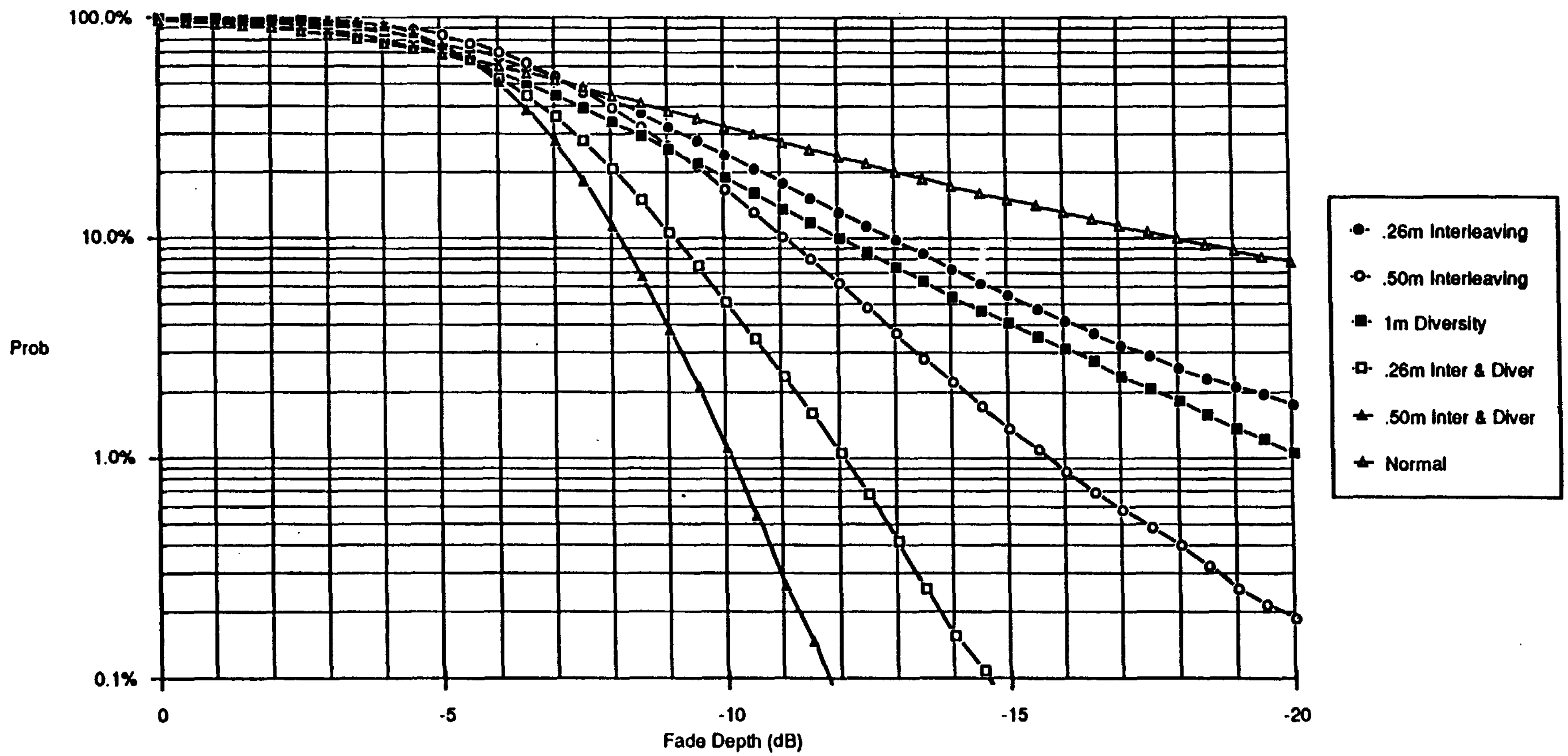


Figure 2-8
Butterworth Model (K=10,μ=-7.5,Sigma=3)

Acquisition and Tracking Algorithms

Synchronization of a Mobile Unit is a multi-step procedure. Figure 3-1 shows the major steps that a Mobile Unit goes through to receive and transmit data (or vocoded voice).

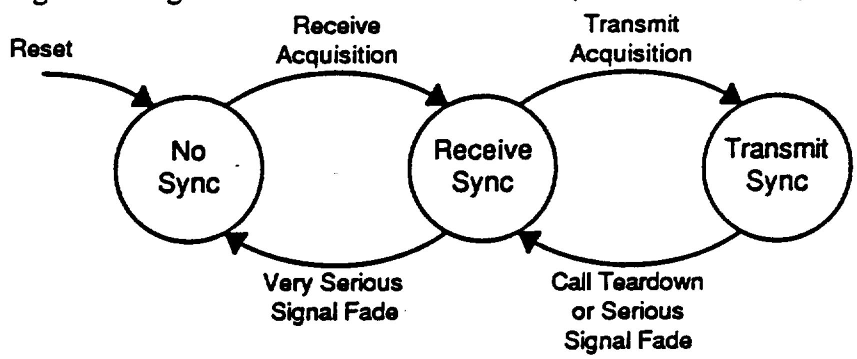


Figure 3-1 — Synchronization State Diagram

Receive Acquisition is attempted whenever the Mobile Unit is not in Receive Sync. Transmit Acquisition is attempted whenever the Mobile Unit needs to transmit data—usually a call setup initiated locally or at the Hub. While in the Transmit Sync state, Receive Sync is maintained—this is in fact essential. When a call is completed or a signal fade of sufficient depth and duration is encountered, the Mobile Unit returns to the Receive Sync state. In the presence of some very serious fades and lengthy (such as parking in an underground garage), the Mobile Unit may lose and need to reacquire Receive Sync.

Receive Acquisition

The following is a description of the steps involved in Receive Acquisition:

Coarse Code Search

The unmodulated pilot sequence transmitted from the Hub is 4095 chips long. The Mobile Unit performs a sequential search of the 4095 chip time uncertainty with Tc/2 time steps. This means that a total of 8190 possible positions must be considered. A simple hypothesis test is used—described later—to determine when the proper code phase has been found. This search takes on the average two seconds to resolve the code phase to within ±1/4 chip time with an initial carrier frequency offset of 9.0 kHz.

Fine Code Acquisition

After the Coarse Code Search is completed, Fine Code Acquisition is performed. A tau-dither phase lock loop is used to adjust the sample clock to nearly optimum sampling positions for chip sampling. This loop is run at a bandwidth of 100 Hz during acquisition—25 Hz during tracking—is quite robust in the presence of fading and shadowing, and can easily acquire Code Sync with initial time reference errors as large as ±6 ppm.

Carrier Phase Acquisition

At the same time that Fine Code Acquisition is started, Carrier Phase Acquisition is started. A ±6 ppm reference error at 1.5 GHz translates to a ±9 kHz carrier frequency uncertainty. A carrier tracking phase lock loop with a bandwidth of 1500 Hz is used and acquires phase lock in less than 200 milliseconds in the presence of fading and shadowing.

System Time Acquisition

A broadcast channel covered by another—synchronous to the pilot—4095 chip sequence is used to transmit system code state, data phase and other necessary system data. This channel is modulated at a data rate of 8.064 MHz ÷ 4095 chips/bit or 1,969.23 bits/sec. Each code symbol contains 4095÷3 or 1365 chips. These relationships make bit sync with the broadcast channel very easy. Figure 1-4 shows the broadcast channel information and various timing relationships. The system code state is transformed into a unit code state by a time shift that is unique to each Mobile Unit. This time shift is done in the Mobile Unit by multiplying the N-bit system code state by an N×N matrix to produce the unit code state. The matrix is unique to each Mobile Unit and is stored in the Mobile Unit at manufacture. Also contained in the Broadcast Channel is the phase of the data channel with respect to the frame boundary—also a 4095 boundary.

When System Time Acquisition is completed, the task of Receive acquisition is also completed and the unit is in the Receive Sync State.

Transmit Acquisition

Whenever a call must be initiated, the Mobile Unit performs Transmit Acquisition. To initiate the Transmit Acquisition process, the Mobile Unit transmits a signal that is very similar to the Broadcast channel that the Hub transmits continuously. The Initial Data Channel— analogous to the Broadcast Channel—contains copies of the System Code State and Data Phase, that the Mobile Unit received on the Broadcast Channel. In addition, the Initial Data Channel contains the Unit ID. The Hub has hardware that continuously scans for these uplink probes. Whenever one is heard, the Hub acquires sync with the signals transmitted from the Mobile in the same way that the Mobile acquires the Hub. When the hub has completed this process, it sends an acknowledgement to the Mobile over the Mobile Unit's Unit Addressed data channel. When the Mobile receives this acknowledgement, it stops transmitting its uplink probe and transistions to transmitting its data via a unit code sequence in the normal manner.

GALAXY MobileStar Demonstration High Level Design

This Section is a general overview of the hardware implementation of the demonstration model of the GALAXY MobileStar modem. First, a separate functional description of the modulator and the demodulator sections are provided accompanied with their corresponding block diagrams; and then, a board level breakdown of the modem and the actual building blocks are introduced.

Modulator

Figure 4-1 illustrates a general block diagram of the Modulator section. The same hardware applies to both the hub and the mobile modems. The analog and the digital portions of the modulator are discussed separately.

Digital Modulator

Figure 4-2 illustrates the building blocks of the digital portions of the Modulator. These Modules are :

- TMS32020 Board (shared with the demodulator)
- Timing Module
- Convolutional Encoder Module
- FIR Filter Module
- Pilot Gain Module
- Combiner Module
- Broadcast Message Generator Module
- Pilot Chip Sequence Generator Module
- Short Sequence Generator Module
- Unit Chip Sequence Generator Module
- Carrier Frequency Direct Synthesizer Module
- Sample Frequency Direct Synthesizer Module

Not shown but referred to is also the CVSD voice encoder. These modules are described below.

<u>TMS32020 Board</u>

The TMS32020 is a card installed in the IBM PC that contains a TMS32020 DSP chip, program and data RAM shared with the PC, control and status registers that the PC uses to monitor the TMS32020, and the TMS32020 I/O bus that is used to interface with the modulator and the demodulator.

<u>Timing Module</u>

This module takes a 32.256 MHz clock and provides all the timing signals for the other modules. The 32.256 MHz clock is divided down to get 16.128 MHz and 8.064 MHz clocks. the 8.064 MHz clock is used with a 4095 counter that provides the timing for the broadcast message and a 12 bit programmable counter controlled by the TMS32020 that provides all the symbol timing. The 16.128 MHz clock is used in the FIR Filter Module. This Module consists of approximately 16 sixteen pin equivalent ICs.

Convolutional Encoder Module

This Module Encodes the Interleaved transmit data and the broadcast data. the encoders are rate 1/3 convolutional encoders. This Module consists of approximately 6 sixteen pin equivalent ICs.

FIR Filter Module

This Module consists of 6 five-pole FIR filters used with both the I and Q channels of the unit transmit data, the modulated broadcast data, and the unmodulated pilot sequence. Each filter has an 8 bit 16.128 MHz output. This Module consists of approximately 24 sixteen pin equivalent ICs.

Pilot Gain Module

This module attenuates the pilot sequence under the control of the TMS32020. This Module consists of approximately 8 sixteen pin equivalent ICs.

Combiner Module

This module combines the unit transmit data, the modulated broadcast data, and the attenuated unmodulated pilot separately for the I and Q channels. The combined result is sent to the Analog Modulator. This Module consists of approximately 12 sixteen pin equivalent ICs.

Broadcast Message Generator Module

This module produces the uncoded broadcast data form the early unit chip sequence and by calculating the symbol chip offset for each broadcast frame. This Module consists of approximately 40 sixteen pin equivalent ICs.

Pilot Chip Sequence Generator Module

This module produces the 4095 pilot chip sequence. It also provides a pilot sync signal that is used to synchronize the unit chip sequence and the short sequence generators. This Module consists of approximately 4 sixteen pin equivalent ICs.

Short Sequence Generator Module

This module produces the 4095 short sequence used to modulate the broadcast data. This Module consists of approximately 4 sixteen pin equivalent ICs.

Unit Chip Sequence Generator Module

This module produces an early and a late version of the unit chip sequence. the late version modulates the unit transmit data. the early version is transmitted in the broadcast message, and is used by the receiver to load it's own unit chip sequence generator and demodulate the data. These are 41 bit PN sequence generators initialized by the TMS32020. This Module consists of approximately 40 sixteen pin equivalent ICs.

Carrier Frequency Generator Module

This module implements a digital direct synthesizer to provide a transmit carrier clock to the Analog Modulator. The resolution of this synthesizer is better than 1 Hz. This Module consists of approximately 30 sixteen pin equivalent ICs.

Sample Frequency Generator Module

This module implements a digital direct synthesizer to provide a 16.128 MHz transmit carrier clock to the Analog Modulator. The resolution of this synthesizer is better than 1 Hz. This Module consists of approximately 30 sixteen pin equivalent ICs.

Analog Modulator

This module takes the I and Q baseband digital signals generated by the Digital Modulator Module, converts them to analog signals and quadrature mixes them up to a 70 MHz IF, 0 dBm transmit signal. The Tx Enable signal is used to gate the transmit IF. When Tx Enable is high, the 0 dBm output is produced. When Tx Enable is low, the TX IF output is less than -40 dBm. The transition time is less than 20 μs.

Demodulator

Figure 4-3 illustrates a general block diagram of the Demodulator section. The same hardware applies to both the hub and the mobile modems. The analog and digital portions of the demodulator are discussed separately.

Digital Demodulator

Figure 4-4 illustrates the building blocks of the digital portions of the Demodulator. These Modules are :

- TMS32020 Board (shared with the modulator)
- Timing Module
- Phase Shift Module
- Integration Module
- CRC Generator Module
- Pilot Chip Sequence Generator Module
- Short Sequence Generator Module
- Unit Chip Sequence Generator Module
- Carrier Frequency Direct Synthesizer Module
- Sample Frequency Direct Synthesizer Module

Not shown but referred to are also the CVSD voice decoder and the Viterbi decoder. These modules are described below.

TMS32020 Board

The TMS32020 is an IBM PC compatible card that contains a TMS32020 DSP chip, program and data RAM shared with the PC, control and status registers that the PC uses to monitor the TMS32020, and the TMS32020 I/O bus that is used to interface with the modulator and the demodulator.

Timing Module

This module takes a 32.256 MHz clock and provides all the timing signals for the other demodulator modules. The 32.256 MHz clock is divided down to get 16.128 MHz and 8.064 MHz clocks. The TMS32020 can advance or retard these clocks by 32.256 MHz ticks. The 8.064

Modulator Digital Boards #1 & #2

These boards implement all the modules described in the Digital Modulator section except for the Transmit Carrier and Sample Clock Synthesizer Modules.

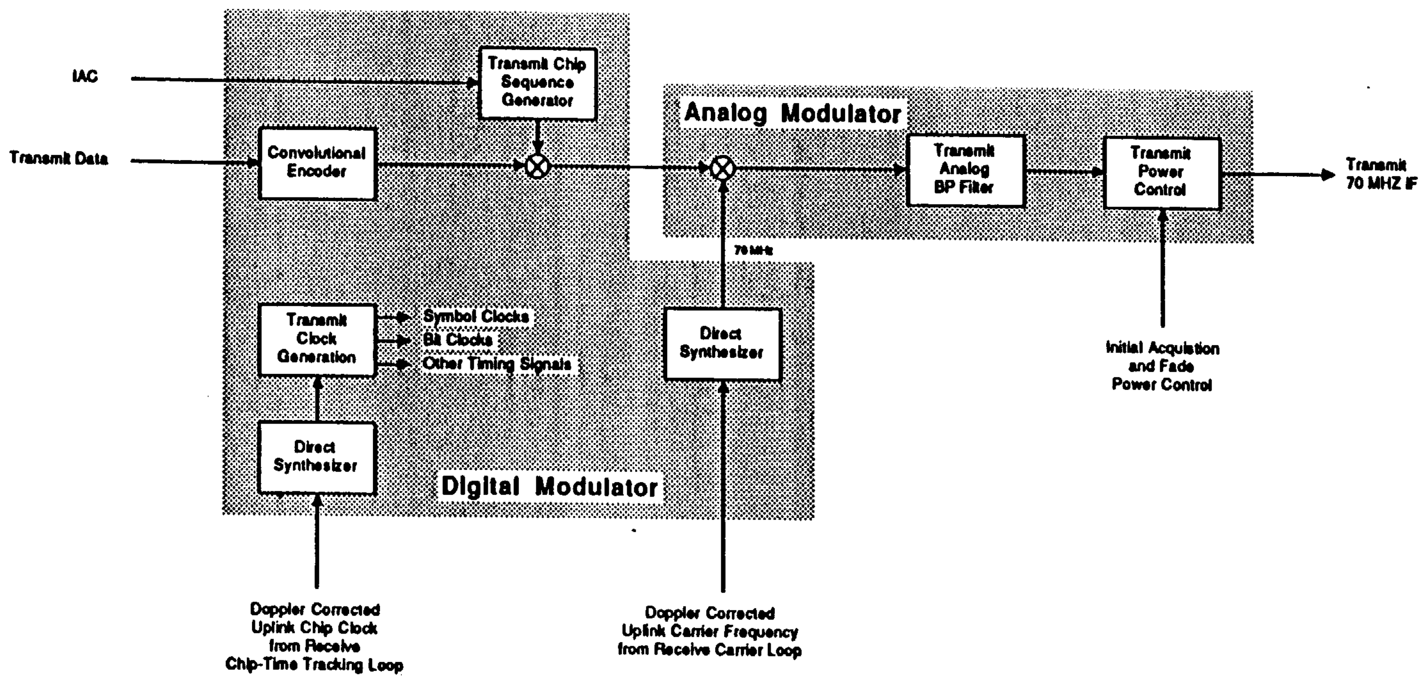


Figure 4-1
GALAXY MobileStar Modulator Block Diagram